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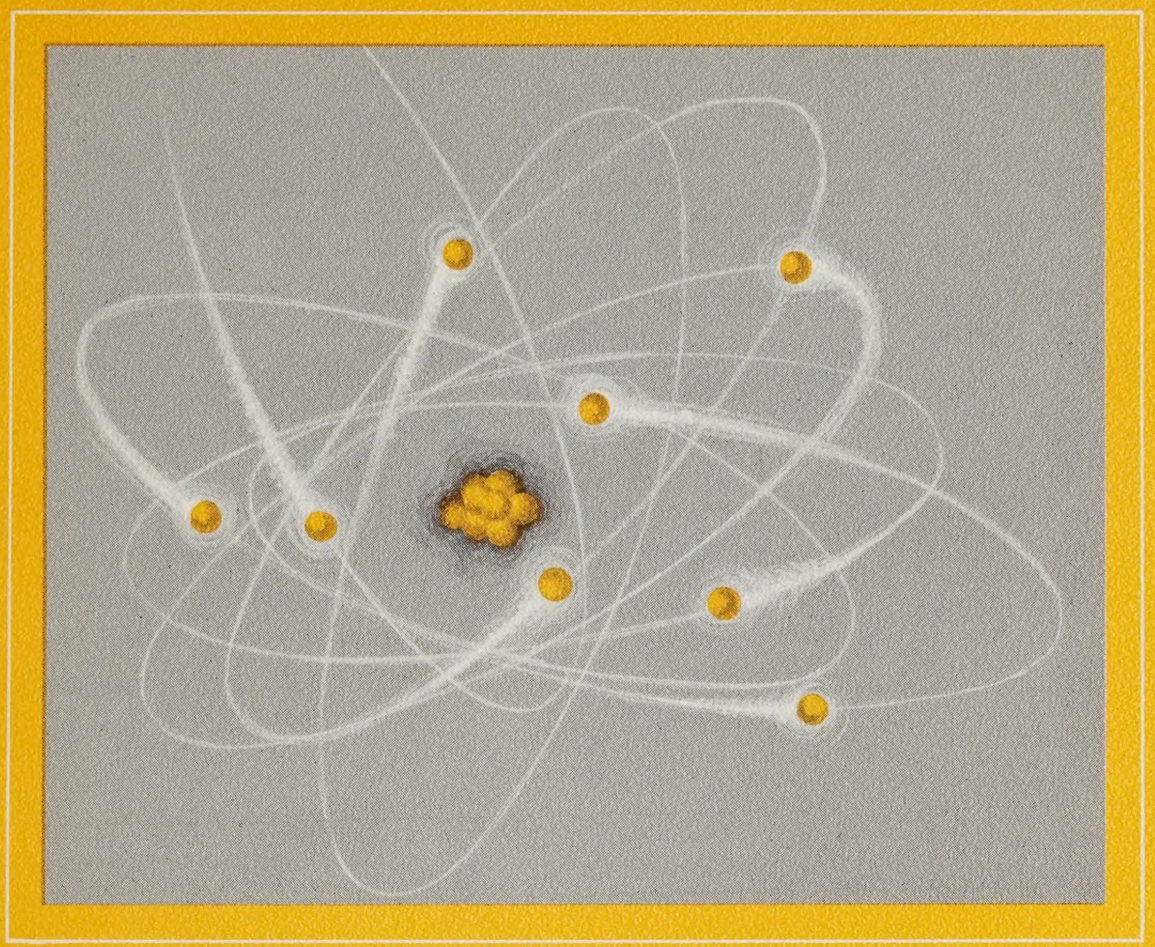

PHYSICS

grades 11, 13

EDUCATIONAL TELEVISION SERIES 1967-68

Educational Television Branch
ONTARIO DEPARTMENT OF EDUCATION
1670 Bayview Avenue/Toronto 17

program schedule

PHYSICS
grades 11, 13

4 programs of 30 minutes each

PROGRAM NO.	CBC 10:00
1	Jan. 19
2	Mar. 14 (9:30)
3	Apr. 8
4	May 15

PHYSICS

4 programs of 30 minutes each for students in grades 11, 13

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general introduction

These programs have been selected from the series of twenty-five PSSC programs shown during the 1966-67 season. Program one would be suitable for viewing by grade 11 students since it would serve as a review of the concepts studied in Unit 1. Program three provides enrichment for Unit IV of the grade 11 course.

The teachers may feel free to use these program outlines as they see fit. It is hoped—at the very least—that teachers will give their students an outline of the major points of interest in each program before the program is broadcast.

Acknowledgement is made of the co-operation of Educational Services Incorporated in giving their permission to edit the films and in allowing the use of information from their own Teacher's Guide to the PSSC films.

program one

INERTIA AND INERTIAL MASS

This program is designed to review sections 20-1 to 20-6 of the PSSC text. It also relates to laboratory experiments III—2, 3 and 4. Segments of the two PSSC films, "Inertia" and "Inertial Mass" are included in this program.

PROGRAM CONTENT

The main ideas presented in the program are as follows:

— Motion is everywhere. There are different types of motion.

— What causes motion? It is obvious that any change in motion requires a force.

Does constant motion require a constant force?

— A demonstration of an object moving with no force is presented. (A dry-ice puck on a horizontal sheet of plate glass is shown. After the initial push, there is no force on it to cause acceleration or retardation.) Motion in a straight line at constant speed is observed. Conclusion: Galileo's Law of Inertia has been demonstrated to be true within the limits of experimental uncertainty.

— If a constant motion results from no force, what is the effect of applying a single constant force? A discussion of the method used to apply the constant force is presented, followed by a demonstration and an analysis of the resulting motion. (Constant force produces constant acceleration).

— The effect of changing the force is shown. In the film segment, the lecturer, Dr. Purcell, doubles the force and finds that 2F produces 2a. He then makes a generalization on this, $\triangle v \propto F$ for the same $\triangle t$, or $a \propto F$.

— A recapitulation of the above ideas is then presented and the program continues with a segment from the film, *Inertial Mass*, in order to present the remaining concepts.

— What is the effect of applying the same force to different objects? How is inertia measured? One dry-ice disc is chosen as a "standard object" and one rubber ring stretched to a given amount is used as a "standard force". A measure of the inertia of this "standard object" is found by measuring the acceleration produced by the constant force. It is 6.1 cm/sec.^{2}

— A different object is presented by fastening two identical dry-ice discs together. The same "standard force" is applied and the resulting acceleration is 3.1 cm/sec.^{2} Since this is half the value obtained with one disc, *and if we assume that inertial masses are additive*, we may state that this experiment suggests that acceleration produced by a "standard force" is inversely proportional to the inertia of the body. This presents a method of comparing inertias.

— Two very dissimilar objects such as a dry-ice disc and a pile of books may have the same inertia. This is checked by measuring the acceleration produced by the "standard force". For two discs the acceleration is 3.1 cm/sec.^{2} for one disc plus a pile of books, the acceleration is 3.2 cm/sec.^{2}

— The next demonstration in the program illustrates how to "measure" the inertia of another different object (in this case, a dictionary is used) by comparing it with the inertia of the "standard object". The acceleration of the disc plus dictionary is 4.2 cm/sec.^{2}

Since $a \propto \frac{1}{\text{Inertia}}$

$$\frac{\text{Inertia of disc + dictionary}}{\text{Inertia of disc}} = \frac{\text{Acceleration of disc}}{\text{Acceleration of disc + dictionary}}$$

$$= \frac{6.1}{4.2}$$

$$= \frac{1.45}{1}$$

However, because the disc represents the "standard object", it has one unit of inertia.

Therefore, using the theorem if $\frac{a}{b} = \frac{c}{d}$, then

$$\frac{a - b}{b} = \frac{c - d}{d}$$

$$\text{Then, } \frac{\text{Inertia of dictionary}}{\text{Inertia of disc}} = \frac{.45}{1}$$

Therefore, Inertia of dictionary is .45 units.

— To re-emphasize that entirely different objects can have the same inertia, a bag of potatoes and the dictionary are each placed on identical discs and pulled with the same force. Since each travels the distance in the same time, it is concluded that their accelerations are the same and therefore, their inertias are the same. At this time, the terms "mass" and "inertial mass" (m_i) are introduced as alternatives to the term, inertia.

— In the film segment, Dr. Purcell, the narrator, summarizes all the experiences so far gained, by the statement $a = \frac{kF}{m_i}$, where the value of the proportionality constant k depends only on the choice of the units for a. F, and m_i.

— The bag of potatoes plus the dictionary which are now known to have the same inertial mass are shown also to possess the same gravitational mass. The fact that there are different physical quantities because there is no connection between the way in which each is measured is emphasized. The fact that inertial mass is proportional to gravitational mass is a result known purely from experiment.

ADDITIONAL INFORMATION

1. Professor E. M. Purcell shared the 1952 Nobel Prize in Physics with Professor F. Bloch for his work in nuclear magnetic resonance. Purcell and Bloch were, however, working quite independently.
2. It should be realized that when it is stated that the object moves under the action of *no* force, only forces acting along a horizontal surface are being considered. This is merely adopting Galileo's method of reasoning. There is, of course, *no*

place in the universe where an object could exist with *no* force on it. This is the reason why the idea of *no unbalanced force* must be introduced for the general statement of the Law of Inertia.

3. Professor Purcell's "trained assistant" in the program is another dry-ice puck sliding down a smooth inclined plane. Because an understanding of how this "trained assistant" operates is needed and is of interest to students, the following discussion is outlined:

   The force, F, which is causing the acceleration is the component of m_2g along the ramp, which equals $m_2g \sin \theta$.

   Because m_2g is a constant force, and θ is constant, then, if the plane is smooth $m_2g \sin \theta$ is constant.

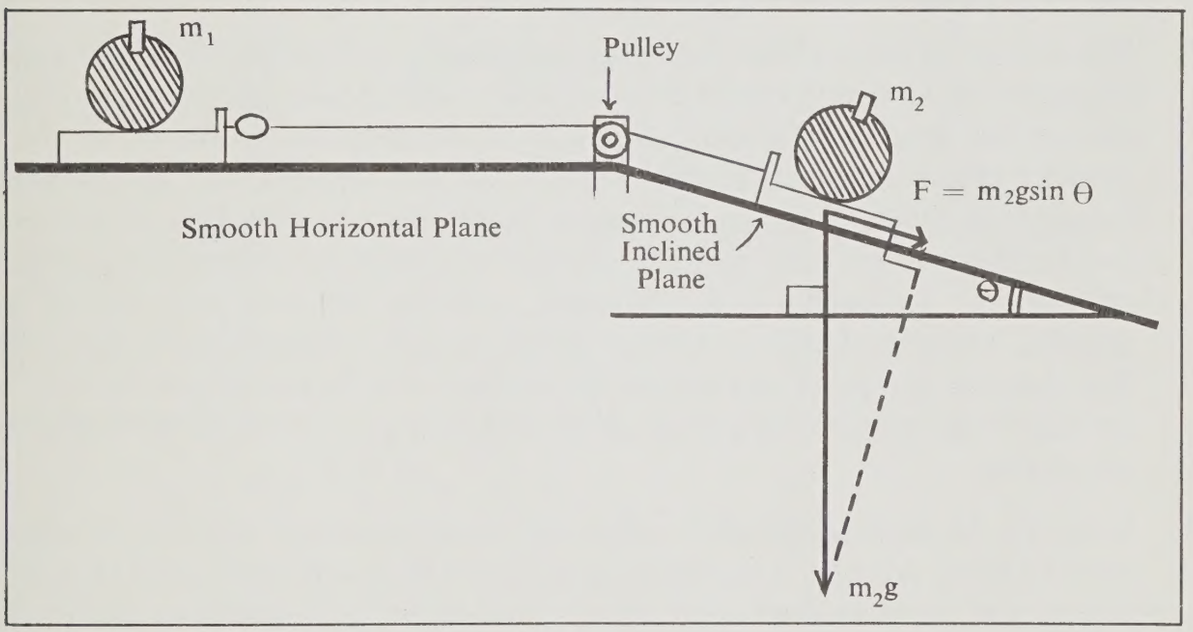
   But F is accelerating both m_1 and m_2

   $\therefore \quad F = (m_1 + m_2)\, a$

   or $(m_1 + m_2)\, a = m_2 g \sin \theta$

   hence $$a = \frac{m_2 g \sin \theta}{m_1 + m_2}$$

   In order to double F one also has to double a. The easiest way to do this is to do what Professor Purcell did in the film, that is, to double $\sin \theta$.



   In the film segment of "Inertial Mass", the same arrangement is used to provide a constant force. Professor Purcell indicated when he referred to his "assistant" that the puck m_2 was the same as the puck m_1.

   If, for simplicity it is assumed that $m_2 = m_1$:

   Then $$a = \frac{m_1 g \sin \theta}{m_1 + m_2} = \frac{1}{2} g \sin \theta$$

   When, however, two discs are tied together in order to see the effect of applying the *same force to a different object*, note that the *exact* same arrangement could not be used to pull the new object, because now there would be a different acceleration and hence a different force.

$$a' = \frac{m_2 g \sin\theta}{2m_1 + m_2} = \frac{m_1 g \sin\theta}{3m_1} = \frac{1}{3} g \sin\theta$$

Therefore, the force on a single disc, m_1, is:

$F = m_1 a = \frac{1}{2} m_1 g \sin\theta$, whereas the force on the double disc is:

$F_1 = 2m_1 a' = \frac{2}{3} m_1 g \sin\theta$, which is *greater*.

It is, however, known that the force on $2m_1$ as shown in the film *is* the same, because the elastic band is stretched to the same amount. In order to accomplish this, $\sin\theta$ must have been reduced for the second demonstration.

4. It should be clarified that the method used to find the acceleration presented in the films is valid only for uniform acceleration. It is only in the case of uniform acceleration that average velocity equals instantaneous velocity at the middle of the time interval. Therefore, subtracting the average velocities over successive one second intervals is the same as subtracting two instantaneous velocities at a time interval of one second. In addition, the above gives an average acceleration, but since the acceleration is uniform, the average acceleration equals the instantaneous acceleration at any instant.

5. It is interesting to note how frequently one assumes the additive nature of physical properties as so-called common-sense rules without proving them. In the first part of the program the additive nature of the independent forces of the two rubber bands is assumed. Furthermore, in the film segment on "Inertial Mass", the additive nature of inertia is assumed. Note, however, that the one experiment could not prove (a) that inertia is additive and (b) that acceleration is inversely proportional to inertia. One, therefore, assumed that the two inertias were additive. Students should be advised not to assume statements without checking. For example, it may be shown that the addition of volumes does not always hold because 50 cc. of water plus 50 cc. of alcohol only produces approximately 96 cc. of solution.

6. It should be emphasized that inertia has been measured without reference to units of force. All that is necessary is to have a standard object (m_2) as a unit of inertia, and compare the inertia of any other object (m_1) with it by means of the relationship, $\frac{m_2}{m_1} = \frac{a_1}{a_2}$, using the same "standard" force for all experiments.

   The students might be given other problems on finding inertia without being told the force, because this gives them a better idea as to the meaning of inertial mass. For example, a certain force gives a mass m_1, an acceleration of 8 m/sec^2, and a mass m_2, an acceleration of 24 m/sec^2.

   A. If m_1 is taken as a standard mass, what is the mass of m_2?

   Solution: $\frac{m_2}{m_1} = \frac{a_1}{a_2}$

   $\frac{m_2}{m_1} = \frac{8}{24}$

Therefore, $m_2 = \frac{1}{3}m_1$.

For example, if $m_1 = 1$ kg. then $m_2 = \frac{1}{3}$ kg.

B. What acceleration would the same force give m_1 and m_2 when they are fastened together?

Solution No. 1:

Let the acceleration of $m_1 + m_2$ be a_3 m/sec^2

$$\frac{m_1 + m_2}{m_1} = \frac{a_1}{a_3}$$

Using the result of (1) $\dfrac{m_1 + \frac{1}{3}m_1}{m_1} = \dfrac{8}{a_3}$

$$\text{Therefore } \frac{4}{3} = \frac{8}{a_3}$$

$$a_3 = 8 \times \frac{3}{4} = 6$$

Therefore, $m_1 + m_2$ would be given an acceleration of 6 m/sec^2 by the same force.

Solution No. 2:

It is worthwhile to note another solution which does not use the intermediate step of part A:

$$\frac{m_2}{m_1} = \frac{8}{24}$$

Using the theorem, if

$$\frac{a}{b} = \frac{c}{d}, \text{ then } \frac{a + b}{b} = \frac{c + d}{d}$$

$$\frac{m_1 + m_2}{m_1} = \frac{32}{24}$$

This states that when m_1 has an acceleration of 32 units, $m_1 + m_2$ has an acceleration of 24 units for the same force. But we are interested in a force which gives m_1 an acceleration of 8 units.

$$\text{Therefore } \frac{m_1 + m_2}{m_1} = \frac{32 \times \frac{1}{4}}{24 \times \frac{1}{4}} = \frac{8}{6}$$

Therefore, the force which gives m_1 an acceleration of 8 m/sec^2 will give $m_1 + m_2$ an acceleration of 6 m/sec^2. In conclusion, *any quantitative information about the force is not needed.*

program two

THE MILLIKAN EXPERIMENT

This program presents the PSSC film, Millikan Experiment. The film features Prof. Francis L. Friedman, M.I.T., and Dr. Alfred Redfield, International Business Machines. A modern version of the famous Millikan Oil Drop Experiment is demonstrated in this film section of the program. The purpose of the experiment is to show that charge comes in multiples of a natural unit. This broadcast will help greatly in the teaching of sections 27-4 and 27-5 of the PSSC text (second ed.).

PROGRAM CONTENT

— The idea is presented that there is a natural smallest unit of charge, or that charge comes in grains which are the same size *electrically*.

— If charge comes in grains, then the force on an object in an electric field carrying one grain should be a certain amount, and for two grains should be twice this, and for three grains three times this and so on.

— The broadcast presents a description of the apparatus used to produce the electric field, and the method of putting into the electric field tiny plastic spheres which carry the grains of charge.

— The plastic spheres are viewed through a microscope. It should be noted that the distance between the parallel plates is 3.1 mm., but the whole field of view of the microscope is only a little over 1 mm.

— Some plastic spheres are placed between the plates. The spheres fall at a steady velocity when pulled by gravity. When the plates are charged, some particles go up and some down. When the charge is reversed on the plates, the particles which were falling now rise, and the ones which were rising now fall. This shows that there are different charges on different spheres. It is also important to notice that each particle moves at its own constant speed.

— A particle reaches its steady speed almost instantly when the electric field is turned on or off (actually in 10^{-5} seconds). We therefore ignore the time it was accelerating when measuring the speeds.

— Standard plastic spheres each 1.8×10^{-6}m. in diameter and 2.8×10^{-14} newtons in weight are used to carry the charges so that any differences in speed between different particles are due solely to different amounts of charge on them.

— When three batteries are connected across the plates, a sphere carrying a certain unknown quantity of charge is kept in balance. The amount of charge *on the plates* is called the "set charge". The particle can be held in balance at any position over the whole field of view. This establishes the fact that there is a uniform electric field between the parallel plates.

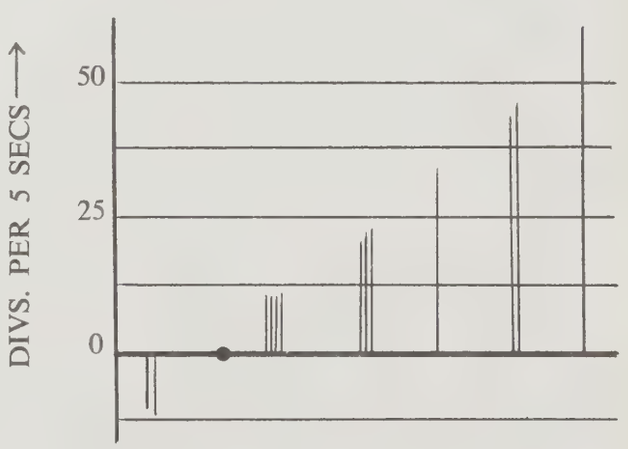
— An extra charge is added to the plates to pull the sphere up again.

— The method of measuring different quantities of charge on the sphere is then discussed. At the start there is a certain quantity of charge on the sphere. When the plates have on them the set charge (provided by three 90V batteries), the electric force on the sphere upwards just balances the gravitational force downwards. The speed of the sphere is zero. When gravity alone acts, the sphere falls 23 or 24 divisions in 5 secs. (Note that the first tick marks zero time and therefore six ticks must be heard to make 5 secs.). The set charge on the plates is then reversed so that now the downward force on the sphere is the force of set charge plus the force of gravity. But since the force of set charge equals the force of gravity, the downwards force is now 2 × force of gravity. It is observed that the particle now moves 48 divs. in 5 secs. or twice the speed obtained with 1 × force of gravity. The conclusion is drawn that the speed is directly proportional to the force and therefore, by comparing speeds, we can measure the force on the sphere .Any change in charge on the sphere will cause a different force to be exerted on it by the set charge. This will become evident by the sphere not being in balance with the set charge on the plates, but moving at a speed proportional to the new unbalanced force which is called the "driving force". The sphere moves at a constant speed because the driving force is always balanced by the force of friction of the air *within* 10^{-5} *secs.* after the sphere starts moving.

— The charge on the sphere is changed by ionizing the air near it or knocking charge off it by means of X-rays. With the first burst of X-rays the charge on the sphere was changed so that with the set charge on the plates is moved up at a speed of 12 divs. in 5 secs. This was repeated many times, that is, changing the charge and measuring the speed. The data from the film segment is reproduced below. The speeds are in number of divs. per 5 secs.

— The integers to the right are multiples of the lowest speed:

$V_1 = 12$	1	$V_9 = 0$	0
$V_2 = 22$	2	$V_{10} = 23$	2
$V_3 = 46$	4	$V_{11} = 60$	5
$V_4 = 34$	3	$V_{12} = 47$	4
$V_5 = 13$	1	$V_{13} = 24$	2
$V_6 = 11$	1	$V_{14} = 11$	1
$V_7 = -12$	−1	$V_{15} =$ lost	
$V_8 = -13$	−1		



This data is shown in the graph.

From this data, one may reason as follows:

a. All speeds are multiples of 11.8 div./5 secs.

b. The charges come on or off the sphere in natural units.

c. Since the speed under gravity alone was 23.5 div./5 secs. and since the set charge balanced the sphere against gravity at the start of the experiment, the force of the set charge on the sphere when in balance, must be the force on 2 natural units of charge.

d. Therefore, the sphere had 2 natural units on it at the start.

— Since the force of gravity on the sphere was 2.8×10^{-14} newtons and since the set charge balanced this when 2 elementary charges were on the sphere, the force per elem. ch. was 1.4×10^{-14} newtons when three 90v batteries were connected across the plates which were 3.1 mm. apart.

— The most important conclusion is that there is a natural unit of charge in which all charge comes. This is called the elementary charge.

ADDITIONAL INFORMATION

1. It should be emphasized that, in general, the terminal speed of a sphere moving in air is not always proportional to the force acting on it. However, in the range of speeds used in this experiment, the proportionality is accurate.

2. What this experiment has really shown is that when X-rays ionise the atoms of the plastic sphere or the gas near it, there is a natural unit charge involved. It is necessary to use other evidence to establish that this unit of charge (the electron) is the same as that involved with other interactions such as electrolysis, or other types of matter such as protons.

   The neutrality of the hydrogen atom establishes that the charge on the proton is equal in magnitude, and opposite in kind, to the charge on the electron. Other evidence that there is but one elementary charge in nature is provided in succeeding PSSC films. It should be established with the students that when the sphere was pulled down with the set charge on the plate, this did not necessarily mean that the charge on the sphere was opposite in sign to that when it was pulled up. Since, in the experiment, gravity alone pulled the sphere down 23.6 divs./5 secs., therefore when it was going down 11.8 divs./5 secs. with a set charge on the plates, there must have been just one less unit of charge on the sphere than when it was balanced. Therefore, during this experiment there was the same kind of charge on the sphere at all times. When it was balanced, there were two units charged on the sphere and in Trial no. 11 the sphere had five *additional* units of charge on it, making a total of seven. Students should establish how many units of charge were on the sphere for each of the other Trials.

3. The experiment in this broadcast does more than establish the existence of a fundamental unit of charge. For the specific plate separation and number of batteries used, it provides a calibration of the electric force on an elementary charge in terms of a gravitational force. The force of 1.4×10^{-14} newtons on each elementary charge, when the plate separation is 3.1 mm. and three 90V batteries are connected across them, is used as a "standard electric force per elementary charge" in much of the succeeding work in the PSSC course.

program three

THE RUTHERFORD ATOM

This program introduces Chapter 32 of the PSSC textbook. The broadcast includes the PSSC film, The Rutherford Atom featuring Prof. Robert Hulsizer of the University of Illinois. By means of qualitative experiments and demonstrations with models, the ideas leading to Rutherford's nuclear model of an atom are strikingly presented. Following this, the film illustrates how Rutherford's prediction of a Coulomb Force Law of repulsion for alpha particles colliding with the nucleus was verified by Geiger and Marsden.

PROGRAM CONTENT

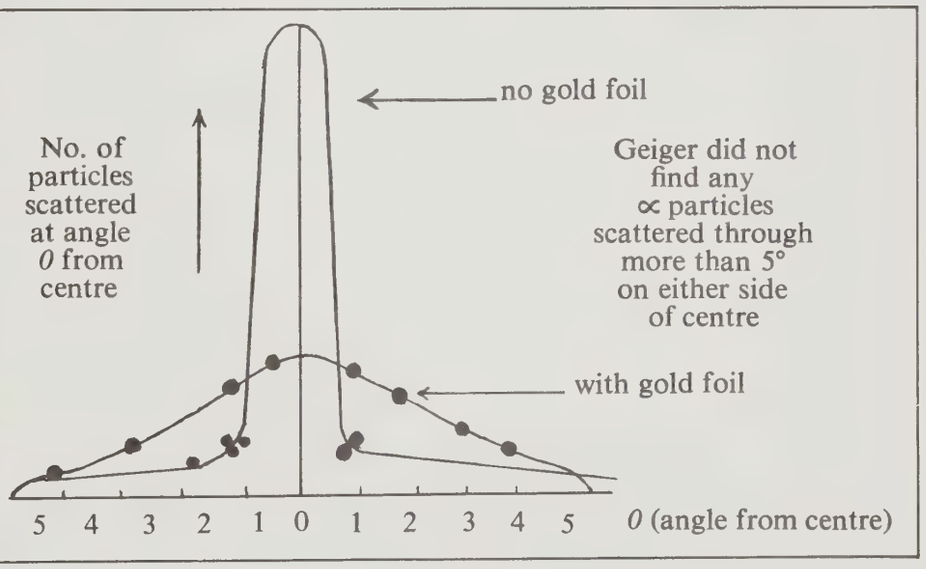
— The viewer is reminded of the nature of alpha particles.

— A comparison is made of the length of particle tracks in air without, and then with, a piece of gold foil in front of the radioactive source (polonium). The two distances, or the longest tracks, are about 4 and 3 scale divisions respectively.

— A comparison is made of the distribution of alpha particles within a narrow beam before and after a piece of gold foil is placed in the path of the beam. The following graphs (Figure 1) show the results of Geiger's original experiment.

— A qualitative experiment showing the distribution of alpha particles in a wider beam (70°) is then illustrated. After finding and marking the edges of the beam, the detector is moved 25° out of the beam and the discovery of wide-angle scattering is made.

Figure 1

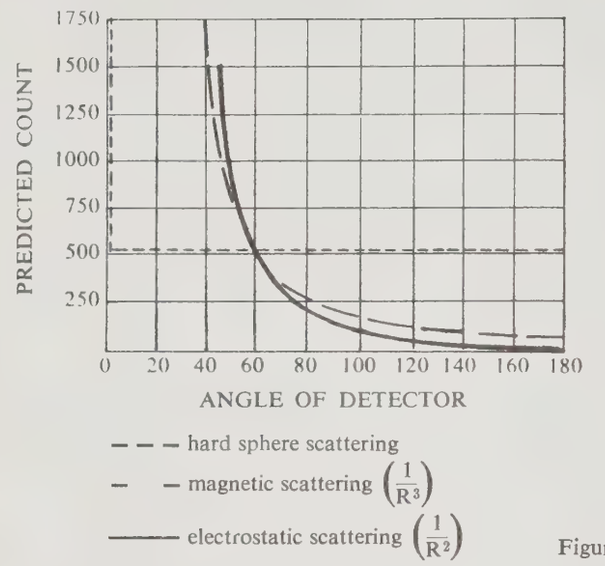

no gold foil
No. of particles scattered at angle θ from centre
Geiger did not find any α particles scattered through more than 5° on either side of centre
with gold foil
5 4 3 2 1 0 1 2 3 4 5
θ (angle from centre)

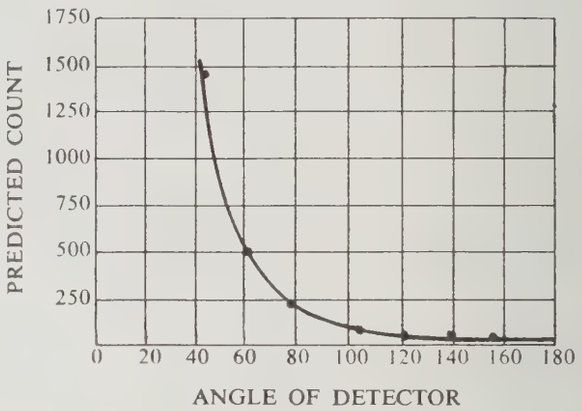
— A model is introduced which shows hot steel ballbearings (representing alpha particles) being rolled down a ramp on to a sheet of waxed paper and then passed through a region which represents the gold foil. The hot balls leave tracks in the waxed paper so that it can be detected whether or not any collisions took place while the particles were passing through the gold foil. It was observed that only six collisions took place out of approximately 200 tracks. On examining the model of the gold foil, it was found that there were hard steel pins at the places where the large deflections took place and that the rest of the space consisted of soft felt only. This leads to the

idea of an atom consisting mainly of empty space which has the very light negatively-charged particles in it and with all the rest of the mass of the atom being very concentrated in a minute space at the centre. Furthermore, this massive core carries a large positive charge and this explains the wide deflections of the positively charged alpha particles.

— The remainder of the film shows how Rutherford checked this view of the atom. He did this by finding out from a detailed study of the deflection angles what type of collision took place between the alpha particles and the nucleus. By "type of collision" is meant the kind of force law which exists between the colliding bodies.

Prof. Hulsizer demonstrates three possible types of collisions:





The dots represent Geiger and Marsden's experimental results. They are compared with the curve characteristic of a $\left(\frac{1}{R^2}\right)$ force as predicted by Rutherford.

Figure 2

a. Magnetic collisions in which the force of repulsion obeys an inverse cube law

b. Contact or hard sphere collisions in which the force of repulsion arises very abruptly

c. Electrostatic or Coulomb collisions in which the force of repulsion obeys an inverse square law.

For the same incident path, each of these produces a different deflection angle after collision.

— Rutherford suspected a Coulomb type interaction, and on this basis he calculated the angles through which the alpha particles would be deflected as a function of how directly they were aimed at the centre of the atom. All the different paths or trajectories are found to be hyperbolae. Prof. Hulsizer shows some of these in a model of an atom.

— Graphs of the number of alpha particles expected at each deflection angle for each kind of collision are shown. These are reproduced herewith (Figure 2), and we can see how Rutherford's prediction was verified.

— Prof. Hulsizer summarises the views on the structure of the atom based on the above results. He states that Rutherford was also able to estimate the size of the nucleus and he shows, by means of a model, the relative dimensions of the whole atom and the nucleus in order to emphasize that most of the atom consists of empty space.

— The program concludes with a brief discussion on the limitations of the Rutherford model of the atom and a suggestion that a new look at the nature of light will provide a clue to solve the difficulties.

ADDITIONAL INFORMATION

1. It should be pointed out to the students that the scattering curves and experimental verification in this program are not the same as those discussed in the PSSC textbook. In the broadcast, the description is in terms of the number of particles scattered into a small angular range located at an average angle S, whereas the PSSC textbook considers the total number of particles scattered through angles greater than angle Θ.

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program four

THE FRANCK-HERTZ EXPERIMENT

This program presents the PSSC film, The Franck-Hertz Experiment featuring Prof. Byron L. Youtz of Reed College, Portland, Oregon. The aim of this program is to show that atoms can take on only certain definite amounts of energy which also means that they can exist only at discrete energy levels or states. In the broadcast, a slightly modified version of the original Franck-Hertz experiment is performed. It shows that when an accelerated electron makes an inelastic collision with a mercury atom, the smallest amount of energy it can give is 4.9 electron volts. The program relates directly to Sections 34-1 and 34-2 of the PSSC textbook.

PROGRAM CONTENT

— A photograph of the bright line spectrum of mercury in both the visible and ultraviolet regions recalls the fact that mercury atoms emit light only at certain distinct frequencies and wavelengths. Attention is directed to the line representing a wavelength of 2537 Angstroms. Since light energy comes from atoms in photons whose energy is proportional to the frequency, all photons coming out of the atom to make up this spectral line will have the *same energy*. The energy of each photon is given by the formula $E = \frac{12397}{\lambda}$ where λ is in Angstroms and E is in electron-volts.

— If atoms lose energy in certain discrete bundles of energy, it seems reasonable to suggest that they can only absorb energy and be raised from one energy state to a higher one in steps having the same discrete energy values. The question then is, "Can we cause a mercury atom to move from one energy state up to another energy state by a process which does not use photons?"

— Can we, for example, make an electron collide with a mercury atom and give it just the right amount of energy to cause it to jump from one energy state to another?

— This idea was tested in 1914 by James Franck and Gustav Hertz who were studying elastic and inelastic collisions between electrons and atoms, and the relationship of this to the emission of light.

— A mechanical model consisting of a dry ice puck (representing a mercury atom) and a ping-pong ball (representing an electron) is used to illustrate the nature of elastic and inelastic collisions. The model, however, cannot establish the idea of absorption of energy only at discrete energy levels.

— The construction of the special vacuum tube used in the actual experiment is illustrated.

The function of the parts is described by means of a schematic drawing:

The control grid A limits the number of electrons passing into the region between A and B.

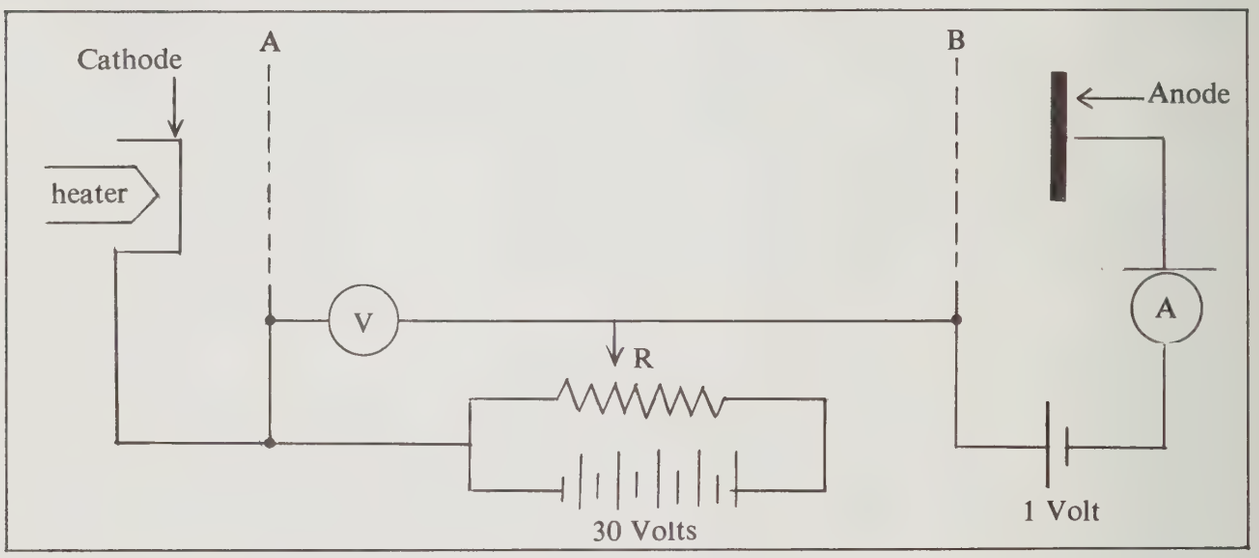
B is the accelerating grid.

V measures the voltage between A and B which is accelerating the electrons across the gap.

This voltage can be varied by means of the potentiometer R.

The anode is held at a potential which is 1 volt negative with respect to B.

Therefore, electrons which pass through B must at least have an energy of 1 electron volt in order to reach the anode and be counted by the current meter A.



— Prof. Youtz shows that with very little mercury vapour between A and B, the current rises smoothly as the voltage is increased up to 30V.

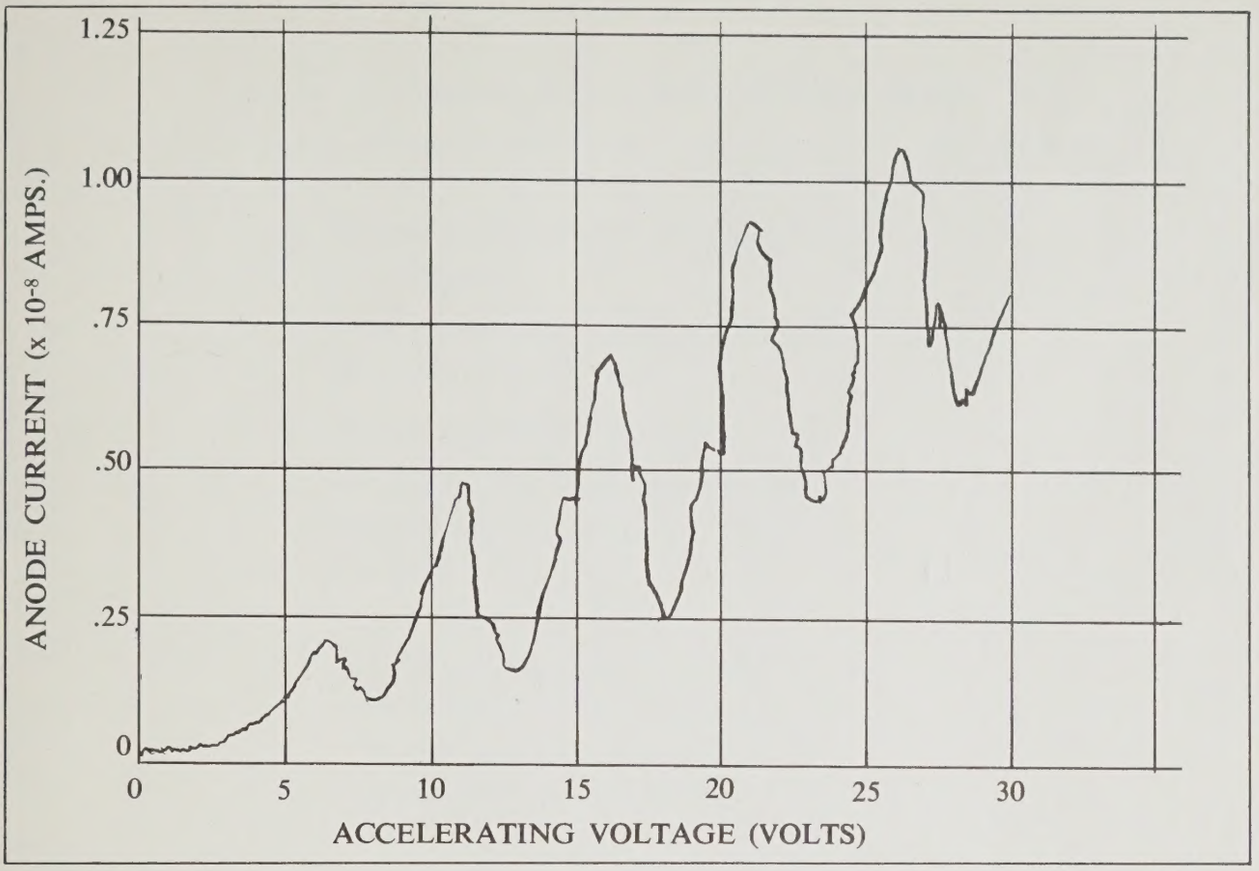
— Mercury atoms are introduced into the path of the electrons by placing the tube (which has a large drop of mercury in it) into an oven at about 160°C.

— Prof. Youtz now predicts that if the voltage is raised as before, the current will rise until a voltage is reached at which the electrons gain just the right amount of energy to deliver the proper sized package to the mercury atoms near grid B. Then they will not have enough energy left to get up the potential kill between B and the anode, and so the current will drop.

— He performs the experiment and the prediction seems to be correct. He then continues to increase the voltage and the current continues to rise and fall alternately.

— Prof. Youtz then repeats the experiment and makes a record of current versus accelerating voltage on an X-Y recorder.

The graph he obtained is similar to the one shown below:



On the average, the distance between peaks is about 4.9 volts. Two possible interpretations of this are given. It is shown that, in either case, it may be concluded that the smallest package of energy which a mercury atom can accept is 4.9 electron-volts.

— This is checked against the relationship $E = \frac{12397}{\lambda}$ for the energy of photons emitted by an atom. For the spectral line $\lambda = 2537$ Angstroms $E = \frac{12397}{2537} = 4.9$ e.v. This is an exact agreement with the prediction.

— Prof. Youtz briefly discusses possible new experiments which should be performed to check up on this new theory.

ADDITIONAL INFORMATION

1. In the complete film, The Franck-Hertz Experiment, there is an epilogue by Prof. James Franck in which he describes an experiment where 4.9 e.v. electrons were used to bombard mercury atoms. The emission of these energy packages in the form of photons to produce the single spectral line of 2537 Angstroms was then observed. This provided an excellent check on the theory.
2. In 1925 Professors Franck and Hertz shared the Nobel Prize in Physics for their research in connection with energy states of atoms.

FOR OPTIMUM VIEWING CONDITIONS

1. Review Teachers Guide well in advance of each telecast.
2. Have the set on and adjusted, sound off before the program begins.
3. Have suggested materials ready.
4. Be sure that you can observe both the program and your students' reactions during the telecast.
5. Assure student comfort by
   — locating the set for best viewing,
   — eliminating glare and reflection,
   — ventilating room properly,
   — placing seats within 20′ of the screen.

This diagram shows the suggested placement of the television set: